Increasing the Longevity of Tungsten Filaments in a Zone Refiner

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Abstract

Zone refining is used for its ability to purify material and grow single crystals [1]. To produce these single crystals, a floating molten zone generated from electron bombardment, passed over the polycrystalline stock. While zone refining like this, the filaments that produce the electron bombardment can blowout during a run. The longevity of tungsten filaments in a zone refiner was investigated. A new lower insert was constructed to prevent the filaments from blowing out. The new lower insert had a shield machined into it to protect the filaments from the impurities striking them. It was found that the new lower insert did not significantly increase the lifespan of the filaments. The longevity of the tungsten filaments was longer in a zone refiner that had a larger pillbox. It is thought that this increased dimensions allows for a reduction in the density of impurities thus limiting the amount striking the filament.

Background

Zone refining: Impurities are soluble in melted material [1]. A zone refiner slowly moves a molten zone through the stock. Impurities follow the molten zone and so are removed.

Creating a molten zone: An electric potential between the filament and stock results in electron emission from the filament. The pillbox helps shape the electric field to focus electron bombardment in a small region of the seed and stock, to form the molten zone.

Filament lifetime: While operating, the filament gradually evaporates away, becoming non-uniform and creating hot spots [2] which can burn the filament out. Impurities may accelerate the process of hot spot growth.

Shield: The shield is designed to protect the filaments from the impurities striking them.

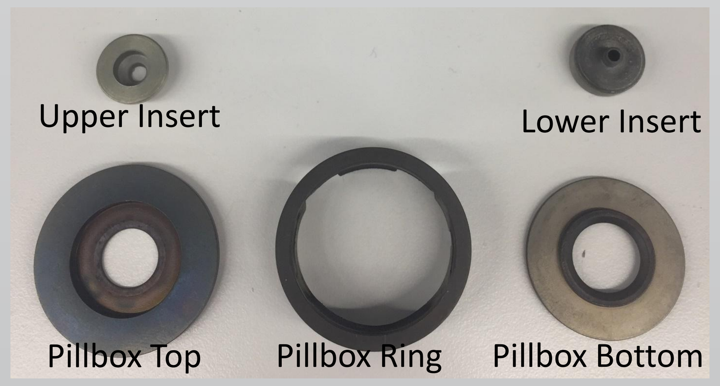

Figure 2. All the pieces that form the pillbox when assembled.

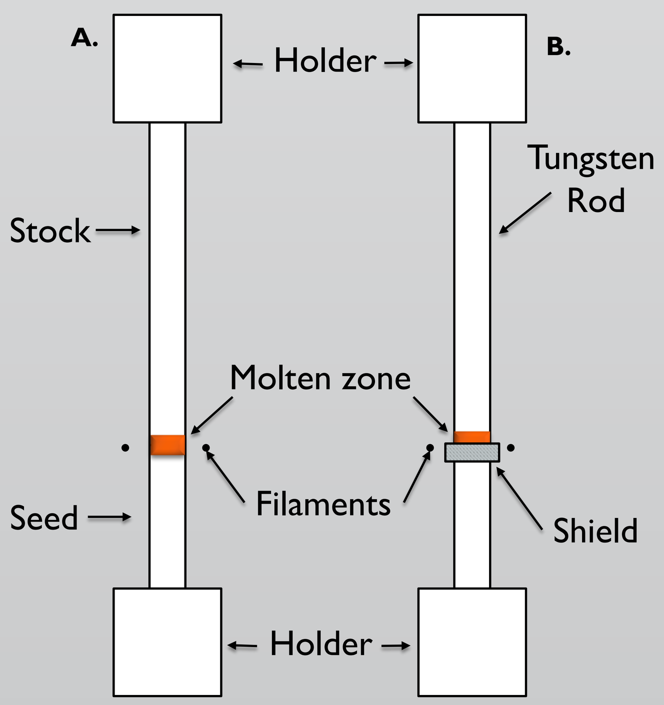

Figure 1. Tungsten zone refiner setup **A.** has the filaments creating a molten zone that is turning the stock to purified seed. Setup **B.** shows a single rod with a shield that the electrons would have to go around.

Methods

- Zone refiner system one was setup only for production which involves a seed and a stock. Zone refiner system two had data collected when it was setup for production and when it had a shield.
- A production setup had 3000 volts applied to the seed and stock. When the shield was in the zone refiner it was tested at 4000 and 4500 volts.
- Each run consisted of 3 passes unless the filaments blew out. The time a single pass took was 15 minutes.
- The emission current to form the molten zone in the production setup was 46mA for the first run. The second run was 45 mA, and the third run was done at 44 mA. The emission current needed for when the shield was in the zone refiner depended on the equation P=IV.

Figure 3. Tungsten filaments that are going around the molybdenum shield. A tungsten rod would go through the middle of the shield. This is only half of the pillbox, missing is the pillbox ring, pillbox top, and upper insert.

Electron Trajectories

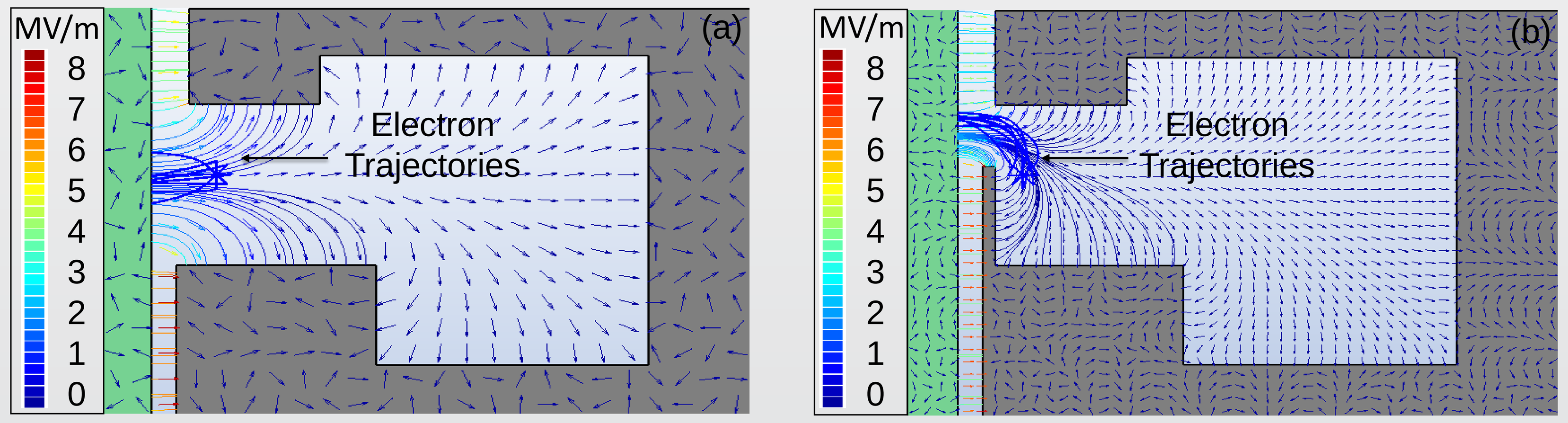

Figure 4. Trajectories of the electron beams that form the molten zone **(a)** cross-sectional view of the pillbox used for production **(b)** cross-sectional view of the pillbox with the molybdenum shield

Electric Field Inside of the Pillbox

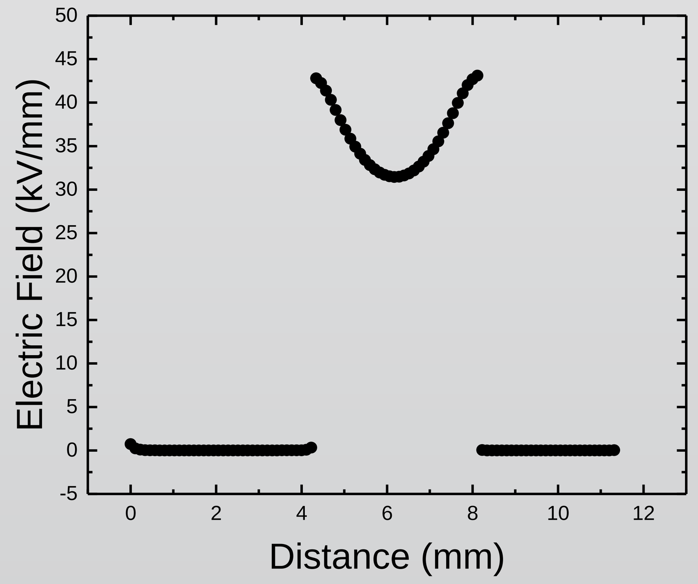

Figure 5. A graph of the electric field created inside of the pillbox when 3000 volts is applied to the seed and stock.

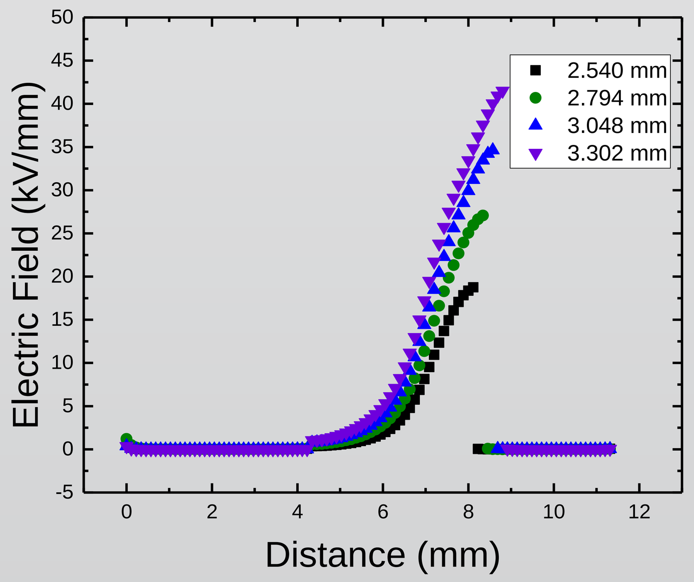

Figure 6. A graph of the electric field inside of the pillbox when 4000 volts is applied to the tungsten rod. Various lengths of the upper insert are used creating different electric fields.

Lower Insert Design

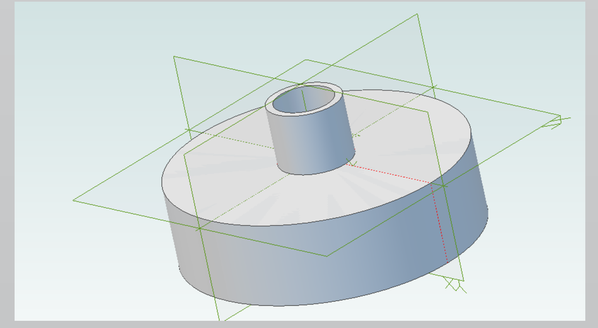

Figure 7. The lower insert with the shield machined into it that will be used to test the longevity of the tungsten filaments. The length of the shield is 2.74 mm.

Filament Blowouts

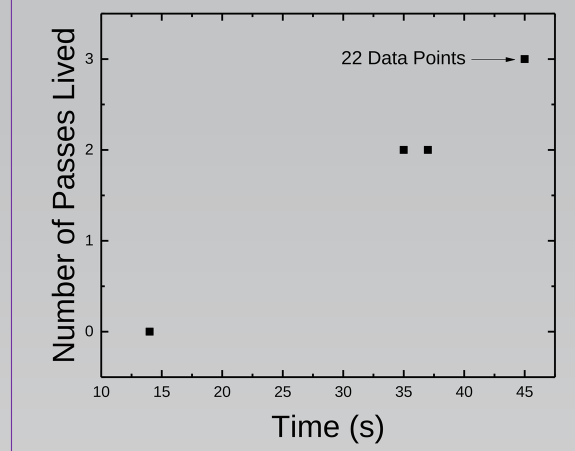

Figure 8. A graph of the number of passes lived for each run in zone refiner system one.

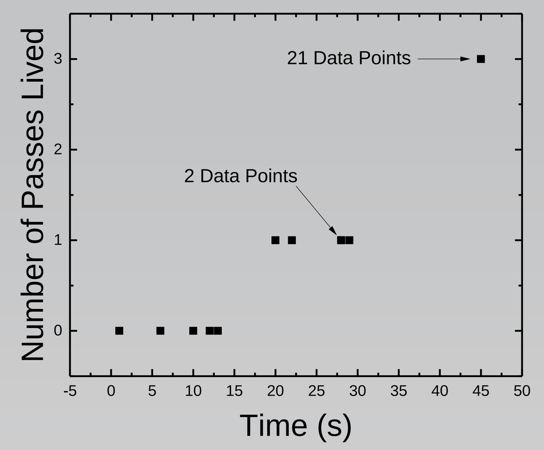

Figure 9. A graph of the number of passes lived for each run in zone refiner system two.

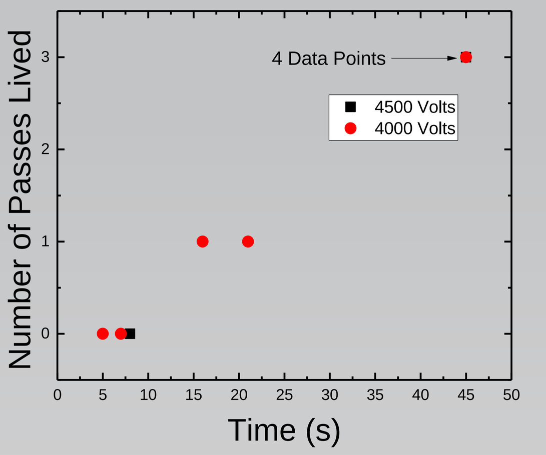

Figure 10. A graph of the number of passes lived for each run in zone refiner system two with a molybdenum shield in the pillbox.

Results

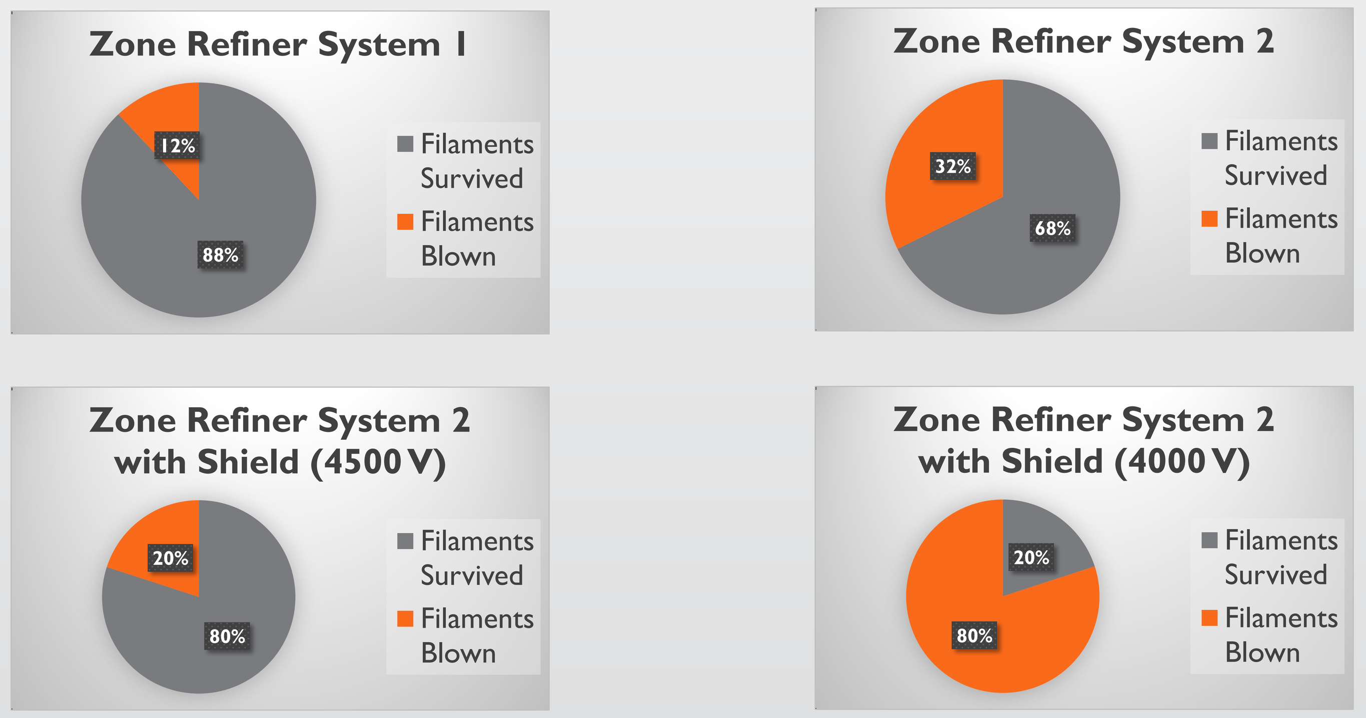

Figure 11. A display of graphs that show the percentage of filaments that blew out and the percentage of filaments that made it all three runs.

- A data point was considered if the filaments survived all three runs or blew out while zone refining. A data point was rejected if the seed broke during a run, there was a shortage in the system, or the run never acquired enough emission current to zone refine.
- When 4500 volts was being used, the zone refiner would surge from particles becoming ionized.

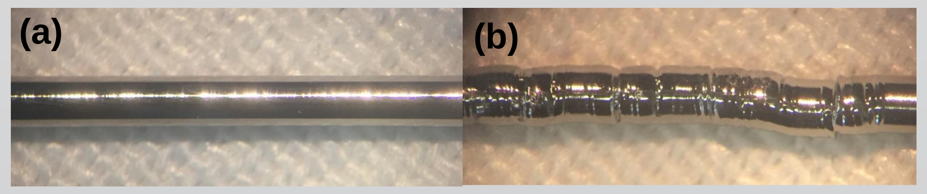

Figure 12. (a) A zone refined piece of tungsten rod **(b)** A zone refined piece of tungsten rod with large notches in it from an increased amount of heat energy.

Conclusions

- The new lower insert did not increase the longevity of the tungsten filaments.
- A larger pillbox may prove to increase the longevity, additional testing is needed to confirm this.
- Reducing the height of the lower insert would allow for the filaments to be lowered. If the filaments are lowered a smaller shield could be emplaced. This might allow for a production setup to be used.
- A more efficient roughing pump could potentially prevent the surging that occurs at high voltages. A piece of tungsten that has been zone refined with surges occurring cannot be used for production.

References

[1] Pfann, W. G. (1958). *Zone melting*. New York: John Wiley & Sons

[2] Walter, J. (1986). Failure of tungsten ribbon filaments by formation and growth of hot spots. *Journal of Applied Physics,60*(9), 3343-3355.

Acknowledgements

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